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#179

PRELIMINARY REPORT ON CASTLE

Project No. A/419/NBS

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MAY 17 1963
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Prepared for

Headquarters, U. S. Air Force
AFOAT, DCS/O

By

A. Glenn Jean
Central Radio Propagation Laboratory
National Bureau of Standards
Washington 25, D. C.

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Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels. Cryogenic Engineering.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Measurements. Infrared Spectroscopy. Nuclear Physics. Radioactivity. X-Ray. Betatron. Nucleonic Instrumentation. Radiological Equipment. Atomic Energy Commission Radiation Instruments Branch.

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Radio Propagation. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Frequency Utilization Research. Tropospheric Propagation Research. High Frequency Standards. Microwave Standards.

•Office of Basic Instrumentation

•Office of Weights and Measures.

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
1401-40-6822	May 13, 1954	3C103

PRELIMINARY REPORT ON CASTLE

Project No. A/419/E/NBS

(13) 22 p
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Prepared for

Headquarters, U. S. Air Force
AFOAT, DCS/O

By

A. Glenn Jean
Central Radio Propagation Laboratory
National Bureau of Standards
Washington 25, D. C.

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Preliminary CASTLE Report [redacted]

Objectives and Preparation for Tests

In accordance with AFOAT-1 Project Authorization A/419/NBS the ~~Central Radio Propagation Laboratory prepared for and conducted~~ electro-magnetic measurements were made during Operation CASTLE. The major tasks undertaken were: under this authorization are outlined below:

(1) Standard monitoring equipment for use by the CRPL and other agencies during CASTLE was designed and constructed; The following reports, which describe this equipment, its operation and calibration, were prepared and distributed to the participating stations.

a) "Equipment for Electromagnetic Measurements to be Made by CRPL during CASTLE",

b) "Notes on the Calibration and Operation of the CRPL Equipment to be used at Remote Field Stations during Operation CASTLE", dated Feb. 8, 1954,

c) "Timing", a memorandum suggesting terminology for reporting the time of arrival of pulses at all stations, dated Feb. 9, 1954,

d) "Proposed Schedule for Recording Peak Field Strength Values from Stations NSS, HPM, and GBR during Operation CASTLE", dated Feb. 9, 1954,

e) Suggested log sheets and additional memoranda were prepared as needed in order to keep the various stations informed of the overall progress, etc.

(2) Estimates of field strengths at remote stations were made and distributed to the participating stations before each event;

(3) At suitable "close-in" (330 km or less) [redacted]

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Bikini Atolls, measurements were performed to:

a) determine the true shape of the entire electromagnetic pulses, to

b) relate the pulse amplitudes to field strength values, to

c) determine the relationship between electromagnetic pulses and bomb phenomenology, and

d) to determine the time of arrival of the electromagnetic pulses which are emitted at the time of an atomic detonation.

(4) Using both broad-band and narrow-band recording equipment, measurements were made at Guam; Maui, T. H.; Boulder, Colorado; Pt. Barrow, Alaska; Ft. Belvoir, Va. near Washington, D. C.; and Stanford, University, at Palo Alto, California to:

a) determine the true shape of the entire electromagnetic pulses as received at each station, to

b) relate amplitudes to field strength values, and to

c) determine time of pulse arrival related to world time, and

(5) At all the locations ~~mentioned above~~, records of field strengths received from low-frequency broadcasting stations and distant atmospherics are to be made to assist in determining propagation attenuation as a function of time and distance.

Close-in Measurements

Measurements were made using broad-band equipment at a distance of about 330 km from ground zero to determine the true pulse shape before being altered materially by the effects of propagation. A six-foot vertical antenna was used to receive the vertically polarized electromagnetic pulse, and a suitable broad-band cathode follower unit was used to atten-

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uate the signal and to distribute it to several oscillo[redacted]ing at different sweep rates and sensitivities.

Additional equipment was used to determine the time of arrival of the electromagnetic pulse. Also, an experiment was carried out using a long wire antenna and an Ampex tape recorder, in an attempt to record any pulses occurring milliseconds or seconds after shot time.

Sample records from ROMEO and KOON are given in this report. The legend with each figure gives the name of the event, the propagation distance in kilometers, the sweep rate in usec/cm along the x-axis, and the sensitivity in volts/meter/cm along the y-axis. The plus and minus signs on each figure indicate the polarity of the electric vector; a minus sign represents a downward electric vector and a plus sign an upward one. A pre-amplifier, which reverses the polarity of signals, was used to record the wave forms shown in Figures 2, 4, 7, and 8. All of the initial half-cycles observed at the close-in stations during CASTLE are negative; this fact was also observed during UPSHOT-KNOTHOLE.

Figure 1 is a ROMEO waveform consisting of a ground wave pulse and a pulse that was reflected from an ionospheric layer height of about 92 km. The peak amplitude of the pulse received along the surface of the earth was about 22 volts/meter, and the peak amplitude of the pulse received after reflection from the ionosphere was about 12 volts/meter. Hence, the ionospheric reflection coefficient for this mode is about 0.6.

The pulse, which is reflected from the ionosphere, is much smoother than the ground wave pulse, indicating a loss of high-frequency energy in the ionosphere.

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The total attenuation of the surface wave over 330 km of sea water (σ = 4 x 10^{-11} emu, and ϵ = 80) is within 3 db of the inverse distance attenuation value at frequencies up to approximately 1.0 Mc. Using this inverse distance relationship, the field strength 20 km from ground zero would be of the order of 360 volts/meter.

Another ROMEO pulse, recorded using a sweep speed of 10 usec/cm, is shown in Figure 2. The pre-amplifier was used in recording this particular pulse; therefore, the first half-cycle, which appears as an upward oscilloscope deflection, corresponds to a downward electric vector. [redacted] Superimposed on this half-cycle are three cycles having a frequency near 80 kc.

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Figure 3 shows the first 16 usec of the waveform in greater detail than either of the preceding figures.

A train of pulses recorded from ROMEO is shown in Figure 4. The first pulse, which overloaded the recording equipment, is about 166 usec long. The succeeding pulses, in order of arrival, are the first, second, third, fourth, and fifth hop sky-wave modes, all of which were reflected from an ionospheric layer height of about 94 km.

Figure 5 is a pulse from KOON comparable to the ROMEO pulse in Figure 2. [redacted] Using the first half cycles of Figures 1 and 6 as an indication of the fundamental frequency, it is

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found that for ROMEO the frequency is about 11 kc and for KOON it is about 45 kc.

In Figure 6 it can be seen that the peak amplitude of the ground wave pulse is about 13 volts/meter, and the corresponding value for the pulse reflected from the ionosphere is about 5 volts/meter. The ionospheric reflection coefficient for this particular mode is about o.5. Figure 6 reveals the extent to which the character of the original pulse was preserved after ionospheric reflection. For comparison with the ROMEO pulse, see Figure 1.

The early detail associated with the atomic detonation is shown in Figure 7, which was recorded using a sweep speed of 12.8 usec/cm.

A train of pulses consisting of the ground wave pulse followed by others reflected from the ionosphere is shown in Figure 8. The individual reflections are not as easily distinguished as those in Figure 4, the corresponding ROMEO presentation.

In Figure 9 a sweep rate of 1 usec/cm and high gain were used to disclose the initial portions of the pulse.

Distant Measurements

A set of ROMEO pulses is shown in Figures 10 through 15 as received at Guam, Maui, Stanford, Barrow, Boulder, and Washington. The length as well as the amplitude of the pulses are related to the propagation distance, and these facts were used at each station to assist in locating the desired pulse on the film records.

A value of field strength expected to be recorded at each station was issued in advance of each shot. The estimates of field strength

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for BRAVO were based upon the predicted value of bomb yield and information gained during IVY relating field strength and distance from a megaton weapon. Fortunately, all CRPL stations except one recorded the BRAVO pulse. Using these results, it was determined that the field strength attenuation beyond 4000 km varied as the inverse square root of the distance and an additional propagation loss at the rate of about 2 or 3 db per 1000 km.

The ROMEO yield was estimated, as shown, to be 12 megatons, using the values of field strength recorded at Maui from ROMEO and BRAVO and a yield of 14 megatons for BRAVO. Since all the events took place at the same time relative to sunrise, the propagation attenuation was considered to be the same for all events.

$$\log Y_R = \frac{E_R}{E_B} \log Y_B$$

Y_R = ROMEO yield

Y_B = BRAVO yield

E_R = ROMEO peak field strength

E_B = BRAVO peak field strength

The maximum center to peak values of field strength recorded at the CRPL stations during CASTLE, which are available at the present time, are plotted against distance in Figure 17. The first letter of the name of each event is placed near the appropriate value of field strength. The attenuation rates between stations for the different events are approximately the same, with the exception of Barrow, Alaska. At this time it is not known why the values of field strength recorded at Guam are as low as they are.

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In Figure 16 is shown a wave-form recorded from KOON at Guam, a distance of 2200 km. The delay times between successive pulses suggest that these individual pulses were reflected from an ionospheric layer height of about 90 km. The wave-form consists of part of the ground wave pulse, followed by the first, second, third, fourth, and fifth hop sky-wave modes. It is of interest to note the high frequency detail present at this distance. Figure 10 is a pulse recorded from ROMEO at Guam, and it is shown for comparison with Figure 16. A reasonable intrepretation of Figure 10 may also be made assuming the ionospheric layer height of 90 km. This choice is mainly based upon the recognizable time delay of 84 usec which is the calculated delay between the first and second hop sky-wave modes. The succeeding reflections due to the third, fourth, and fifth hops are not clearly separated as in Figure 16. The first half-cycle seen in Figure 10 is taken to be part of the ground wave pulse. The one-hop pulse received from KOON at Guam is similar to the first-hop sky-wave pulse seen in Figure 6 which was recorded at 330 km; it contains components at much higher frequencies than the pulses received at Guam from ROMEO. The ratios of peak amplitudes of the ground wave pulses to the peak amplitudes of the first-hop sky-wave pulses suggest that the ionospheric reflection coefficient for KOON was approximately twice the value for ROMEO.

In Figure 18, preliminary times reported by each station for the first five events are tabulated. Better agreement between the values of T_d (detonation time) may be achieved after more accurately calculating T_p (propagation delay time for the pulse) and T_s (propagation delay time

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for the WWV or WWVH seconds pulses).

The relatively low value of field strength recorded at Barrow for ROMEO may be found to be related to a disturbance of the earth's magnetic field which existed on that day. The attenuation of field strength in db/1000 km from Maui to Barrow is about 3 db for BRAVO and 5 db for ROMEO. The Barrow, Alaska magnetic K figures for the three hour period containing the BRAVO and ROMEO detonation times are respectively 2 and 5.

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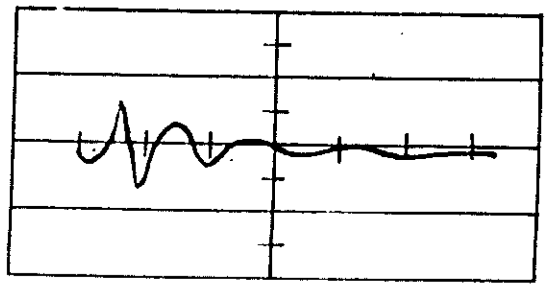

Fig. 10

ROMEO
Guam, 2200 km path
Sweep rate 100 usec/cm
Sensitivity 1v/m/cm

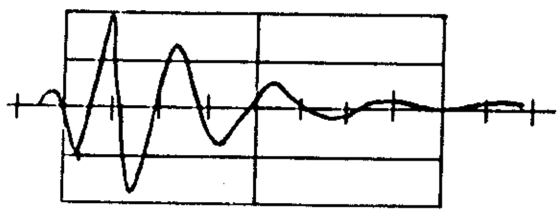

Fig. 11

ROMEO
Maui, 4200 km path
Sweep rate 68 usec/cm
Sensitivity 0.98 v/m/cm

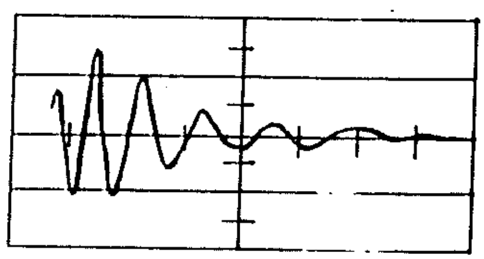

Fig. 12

ROMEO
Stanford, 7400 km path
Sweep rate 125 usec/cm
Sensitivity 0.280 v/m/cm

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Fig. 13

ROMEO
Barrow, 6800 km path

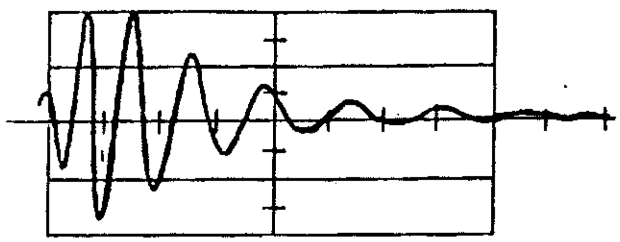

Fig. 14

ROMEO
Boulder, 8900 km path
Sweep rate 100 usec/cm
Sensitivity .164 v/m/cm

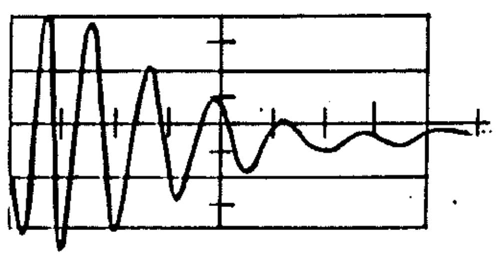

Fig. 15

ROMEO
Wash. D. C., 11,100 km
Sweep rate 100 usec/cm
Sensitivity .035 v/m/cm

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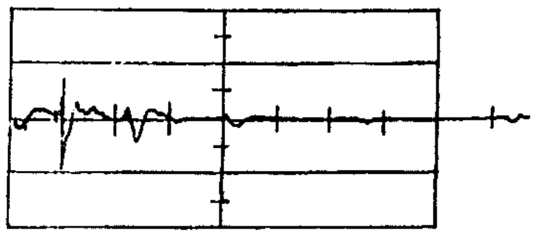

Fig. 16

KOOW
Guam, 2200 km path
Sweep rate 70 usec/cm
Sensitivity .25 v/m/cm

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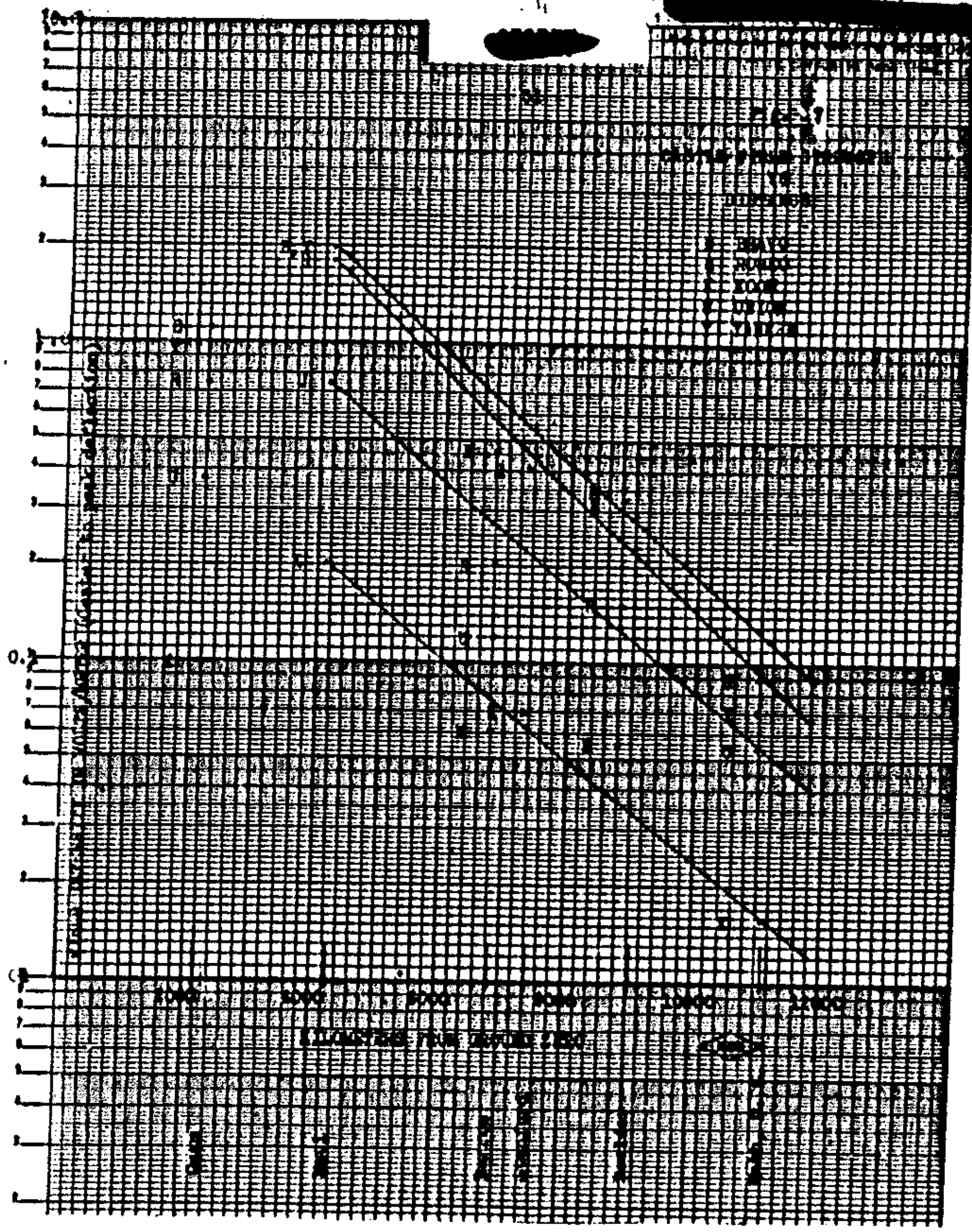

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	BRAVO - Mar. 1 T_d = 1845:00.009		ROMEO - Mar. 26 T_d = 1830:00.376		KOON - Apr. 6 T_d = 1820:00.409		UNION - Apr. 25 T_d = 1810:00.689		YANKEE - May 4 T_d = 1810:00.164	
Station	T_o	T_d	T_o	T_d	T_o	T_d	T_o	T_d	T_o	T_d
Close-in	:59.996	:00.009	:00.363	:00.376	:00.396	:00.409	:00.676	:00.689	:00.141	:00.154
Guam	:59.996	:00.010	:00.363	:00.377	:00.398	:00.412	:00.677	:00.691	:00.139	:00.153
Maui	:00.023	:00.009	No time record		[illegible] ~~:00.393~~	[illegible] ~~:00.413~~	No time record		:00.170	:00.156
Stanford	No records		:00.388	:00.377	:00.424	:00.413	:00.703	:00.692		
Barrow	:59.963	:59.959	:00.384	:00.380	:00.394	:00.407				
Boulder	:00.034	:00.012	:00.401	:00.379	:00.430	:00.412	:00.713	:00.691	:00.181	:00.159
Washington	:00.047	:00.009	:00.418	:00.380	:00.451	:00.413	:00.731	:00.693	:00.198	:00.160

Figure 18. Preliminary times (GMT) reported by CRPL stations for the first five events.

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The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

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Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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DEPARTMENT OF DEFENSE
WASHINGTON HEADQUARTERS SERVICES
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[redacted]

28 JAN 2013

Subject: OSD MDR Case 12-M-1572

Dear [redacted]:

We have reviewed the enclosed document in consultation with the Department of Energy (DOE) and have declassified it in part. OSD and DOE excised information is exempt from declassification under Executive Order 13526, section 6.2(a). Section 6.2(a) protects "Restricted Data" and "Formerly Restricted Data" information in conformity with the provisions of the Atomic Energy Act of 1954, as amended, and regulations issued under that Act.

OSD stands as the appellate authority and will coordinate any appeals regarding this case. A written appeal must be filed within 60 days explaining the rationale for reversal of the decision. Reference should be made to OSD MDR Case 12-M-1572. Letters of appeal should be sent to the following address:

WHS/ESD Records and Declassification Division
Attention: Robert Storer
4800 Mark Center Drive
Suite 02F09-02
Alexandria, VA 22350-3100

If you have any questions, contact me by e-mail at Records.Declassification@whs.mil or by phone at 571-372-0483.

Sincerely,

Robert Storer

Robert Storer
Chief, Records and Declassification Division

Enclosures:
1. MDR request
2. Document 1

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1155 DEFENSE PENTAGON
WASHINGTON, DC 20301-1155

FEB 14 2013

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
(ATTN: DTIC-OQ INFORMATION SECURITY)
8725 JOHN J. KINGMAN ROAD, STE 0944
FT. BELVIOR, VA 22060-6218

SUBJECT: OSD MDR Cases 12-M-1572 and 12-M-1573

At the request of [redacted], we have conducted a Mandatory Declassification Review of the attached documents under the provisions of Executive Order 13526, section 3.5, for public release. We have declassified the documents in part. We have attached a copy of our response to the requester on the attached Compact Disc (CD). If you have any questions, contact me by e-mail at storer.robert@whs.mil, robert.storer@whs.smil.mil, or robert.storer@osdj.ic.gov or by phone at 571-372-0483.

Robert Storer

Robert Storer
Chief, Records and Declassification Division

Attachment:
CD